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# PHILCO CORPORATION

A SUBSIDIARY OF Ford Motor Company

LANSDALE DIVISION • Church Road, Lansdale, Pennsylvania

26 June 1963

Armed Services Technical Information Agency
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Arlington 12, Virginia

Subject: Contract No. DA 36-039-AMC-01464(E)
Order No. 21039-PP-63-81-81
First Quarterly Progress Report
Period 27 December 1962 to 27 March 1963

Gentlemen:

Reference is made to the subject report distributed to you on 7 June 1963. The USAEMA order number shown on the cover and title pages is incorrect. Kindly revise it to read 21039-PP-63-81-81 in lieu of 21039-PP-63-81-81.

Thank you.

Very truly yours,

PHILCO CORPORATION
LANSDALE DIVISION

John R. Gordon
Contract Administrator

JRG/kaw

cc: L. Coblents/USAEMA, Phila.
J Juaninett/USAEMA, Phila.

PHILCO CORPORATION

LANSDALE DIVISION

Lansdale, Pennsylvania

# PEM for GOLD-DOPED GERMANIUM INFRARED DETECTOR TYPE IR400

First Quarterly Progress Report
27 December 1962 to 27 March 1963
Contract No. DA-36-039-AMC-01464(E)
Order No. 21038-PP-63-81-81
Placed by USAEMA, Philadelphia, Pa.

Philco Project No. H-200

PHILCO CORPORATION
LANSDALE DIVISION
Lansdale, Pennsylvania

# PEM for GOLD-DOPED GERMANIUM INFRARED DETECTOR TYPE IR400

First Quarterly Progress Report

Period Covered:

27 December 1962 to 27 March 1963

Contract No. DA-36-039-AMC-01464(E)

Order No. 21038-PP-63-81-81

Placed by USAEMA, Philadelphia, Pa.

Object of Study:

Production Engineering Measure (PEM) in accordance with Step I of Signal Corps Industrial Preparedness Procurement Requirements (SCIPPR) No. 15, dated 1 October 1958, for p-type, gold-doped germanium infrared detector, Form 2 per Specification SCS- 36A, dated 8 April 1960. Work includes establishing a pilot line to manufacture the detector, demonstrating the capability to fabricate and test 15 units meeting applicable specifications per 8-hour shift.

Philco Project No. H-200

Report prepared by D. Skvarna

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## SECTION I - ABSTRACT

The reported work is on a PEM for producing p-type gold-doped germanium infrared detectors, Type IR400.

The report covers the first quarter of the contract period. The work for the period is divided into three main categories: gold-doped germanium crystal growing, material evaluation and testing, and barium fluoride transmission window sealing to glass and metal.

The procedures involved in material and device fabrication and testing are discussed. Evaluation data is included in tabular and graphic form.

Problems encountered in device fabrication and testing and difficulties experienced in the barium fluoride sealing program are also discussed.

## SECTION II - PURPOSE

The purpose of this Production Engineering Measure is to develop and demonstrate production facilities capable of producing p-type, gold-doped germanium infrared detectors. The detectors shall be Form 2 per Specification SCS-36A, dated 8 April 1960. The production capability to be demonstrated on a pilot line basis shall be equipped to manufacture and test 15 units meeting applicable specifications per 8-hour shift. A production type run of 50 units is to be performed to demonstrate the specified capability.

Performance of the contract also calls for furnishing of the following:

1. Engineering samples (6 each)
2. Preproduction samples (12 each)
3. Special tooling consisting of:
    a. Copper-Kovar Multi-unit Bonding Fixture
    b. Special Coil for R-F Bomber
    c. Special Chamber for R-F Bomber
    d. Variable Speed Chopper (100 cps to 40 kc)
    e. Exposure Test Console
4. Quarterly reports (30 copies/quarter)
5. Final Engineering Report (30 copies)

6. Bills of Materials and Parts (2 copies)
(Forms DD-346 and DD-347)

7. General Report on Step II (6 copies)
(Covering a rate of 50 p-type, gold-doped germanium infrared detectors meeting the applicable specifications per 8-hour shift).

## SECTION III - NARRATIVE AND DATA

### 3.0 Introduction

During this report period effort was concentrated both on the metallurgical aspects of the infrared detector program and on transmission window investigations. Detector material was prepared and characterized and devices were fabricated. Transmission window investigations dealt with both window composition and sealing procedures, since transmission window efficiency ultimately affects the detectivity of the device.

### 3.1 Metallurgical Program

#### 3.1.1 General Objectives

The metallurgical program for specification and production of high detectivity material has as its objectives:

a. Optimization of gold concentration in the germanium,

b. Perfection of crystal structure necessary to accommodate the optimum gold concentration,

c. Optimization of compensation concentration,

d. Production of the desired material reproducibly and with high yield.

### 3.1.2 Approach

In order to evaluate the gold-doped germanium from the standpoint of infrared detection, a range of resistivities, carrier concentrations and crystal perfection is required. This range of resistivities, concentrations, and crystal perfection is most easily obtained by selecting zones from a vertically pulled ingot (Czochralski method). The selected zones are characterized by parameter measurements and fabricated into infrared detectors. The primary parameter in evaluation is the detectivity (D*).

The evaluation data will permit selection of the optimum detector material, following which zone leveling techniques will be used to reproduce optimum material on a larger scale.

### 3.1.3 Source of Material

Germanium from three suppliers has been purchased to obtain the purest germanium from the standpoint of low-lying p-type impurities. Selected samples were zone refined prior to doping. A preliminary series of ingots was gold doped and pulled by the Czochralski method. A second series of ingots will be gold doped and compensated with the amount of antimony calculated to fill the low-lying p-type levels plus a percentage of the lower gold level.

### 3.1.4 Material Characterization

To characterize the material, the following parameters are measured on every fifth wafer sliced from the selected zone:

a. Resistivity, Mobility, Carrier concentration } at 300°K and 77°K

b. Dislocation count

c. Resistivity profile across the wafer

d. Cooling ratio (ratio of resistivity at 77°K to resistivity at 300°K)

e. Gold and compensation concentrations (calculated).

### 3.1.5 Material Prepared and Data

During this first report period, five ingots were pulled. Material received from Rare Metals Derivatives was zone refined with three passes. A low dislocation <111> seed ingot was pulled, and seeds cut from this ingot were used to pull the crystals. Each ingot was doped to 1 x $10^{15}$ gold atoms/cc and 8 x $10^{13}$ antimony atoms/cc. Dislocation densities measured at the seed ends of the ingots ranged from 5000 to 7000 pits/$cm^2$. In each case, high dislocation density occurred before a concentration of 2 x $10^{15}$ gold atoms/cc was reached. To correct this situation, slow pull rates of 3/8" to 1/2" per hour will be necessary on future ingots. The ingots had satisfactory cooling ratios and the maximum cooling ratio

occurred in the 1.5 - 2.3 ohm-cm range when dislocation density was also high. The crystals grown were designated as B119, B120, B125, B128, and B129. Pertinent comments are given below for each of these five crystals.

Crystal B119

This crystal had a high dislocation density near the seed end and parameter measurements were difficult, due to slippage planes. Evaluation was also difficult due to the high dislocation density. It was decided to discontinue the evaluation on this particular crystal and proceed to Crystal B120.

Crystal B120

Starting at the seed end (wafer #1) and continuing to wafer #15, approximately 30 detectors were made and evaluated. The parameter measurements of this crystal are shown in Table 1, and the results of the evaluation are shown in Table 2 and Figure 1. The resistivity range used was 3.4 ohm-cm to 2 ohm-cm. The dislocation count in this region varied from 5800 to >10,000 etch pits/$cm^2$.

Crystals B125 and B129

These crystals have been wafered and are ready for slicing into bars. Data on these crystals will be available for the next report period.

Crystal B128

This crystal is presently under evaluation. Insufficient data is available to report for this quarter.

## 3.2 Detector Fabrication and Testing

### 3.2.1 Parts, Fixtures and Jigs

During the report period the following parts were designed and built or purchased:

a. Machine lapping fixtures

b. Carbon alloying boats

c. Kovar tabs

d. Cell mounts

e. Evaluation dewars.

### 3.2.2 Detector Processing

The ingots are sliced with a diamond saw into wafers 0.100" thick, and are approximately 0.75" in diameter. The wafers are then cut into bars 0.100" x 0.100" x 0.400". The bars are reduced in dimension by machine lapping to 0.090" x 0.090" x 0.375". The detector size selected as optimum for fabrication is 0.08" x 0.08" x 0.375".

The germanium bar is etched for two minutes in CP4* at 27°C. The material removal rate of this etch is about 0.001" per minute. After the bar has been etched and rinsed in deionized water, it is sandwiched between kovar tabs and placed on a copper cell mount. The assembly is alloyed in a hydrogen atmosphere at 400°C for two minutes. Figure 2 illustrates this assembly. Platinum leads are soldered to the unit and the unit is placed into a demountable dewar that is fitted with a silicon window, and evacuated to a pressure of 15 microns.

### 3.2.3 Detector Testing

The unit is tested against a 500°K blackbody. The signal to noise ratio is taken and the D* is determined. Figure 3 shows the testing circuits.

### 3.2.4 Problems and Possible Solutions

The evaluation method has three disadvantages:

a. The alloying fixture presently in use does not provide constant pressure to the tabs during the alloying process. The resulting alloy is spotty, which creates noisy contacts.

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* CP4 consists of hydrofluoric acid, nitric acid, acetic acid, and bromine.

b. The copper cell mount introduces contaminants into the etch, which results in contaminated surfaces that yield poor signal and high noise. Etching of the detector in a jet of running etch has reduced the contamination, but the method is not entirely satisfactory.

c. The pressure inside the demountable dewar on the forepump is not low enough to prevent high heat conduction to the outer walls. The heat conduction to the dewar walls plus the bias power dissipation raises the detector temperature above the normal operating temperature, resulting in lowered S/N and D* readings. A diffusion pump in addition to the forepump may solve this problem.

It should be pointed out that the problems inherent in the material evaluation are also applicable to the fabrication of the end device because the same processing steps are involved.

An approach to eliminate or minimize the mentioned disadvantages is presently under consideration and will involve a new fabricating jig and testing dewar and elimination of the copper parts by substituting corrosion resistant materials.

In place of mounting the germanium onto a copper cell mount, a germanium "sandwich" will be made between two kovar tabs. Leads

will be soldered to these two tabs and the unit will be immersed in liquid nitrogen for testing. Modulation of the background radiation by the bubbling liquid nitrogen may be a problem with this method, but proper shielding should minimize this effect. The testing configuration may be similar to the configuration in Figure 4.

The new testing configuration should have the following advantages:

a. Better alloying due to improved jigging, also a less complex jig,

b. Copper contamination of the etch will be eliminated by elimination of the copper cell mount,

c. Operating temperature will be attained by direct immersion in liquid nitrogen.

## 3.3 Transmission Window Investigations

### 3.3.1 General

The selection of window material is influenced by several factors, such as

a. Transmittance

b. Cost

c. Durability under environmental conditions of temperature, vibration, humidity, pressure, etc.

d. Good properties under vacuum

e. Ability to provide reliable seals to glass or metal.

Barium fluoride exhibits superior transmittance to 9.5 microns, resulting in enhanced detectivity of any detector operating within this spectral region. Furthermore, its low reflective loss eliminates the need for anti-reflective coatings. Another advantage is the transmission in the visible portion of the spectrum, allowing visual alignment of optics. While these advantages make barium fluoride attractive, this material is generally avoided in windows due to its softness, water solubility, and high coefficient of thermal expansion.

It has been determined experimentally that an increase of detectivity of 25 - 30% can be expected by the use of a barium fluoride window as opposed to a silicon window.

### 3.3.2 Barium Fluoride Sealing Program

Barium fluoride window seals to glass have been unsuccessful to date, but limited success was encountered with barium fluoride seals to #304 stainless steel and copper.

Twelve attempts to seal barium fluoride windows to glass as described by Greenblatt* were unsuccessful. The barium fluoride

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* M. H. Greenblatt, "Sealing a Calcium Fluoride Window to Glass," Rev. Sci. Instr., 29, 738, Aug. 1958.

windows were 35 mils thick; half were 3/4" diameter and the rest were 1/2" in diameter. The glass used was Corning 7052, with silver chloride as an intermediary between the glass and the barium fluoride window. Hardy and Harmon #2265-01 silver paint was applied and fired into the areas that were to be in contact with the AgCl. A programmed temperature controller was used to cycle the furnace slowly and uniformly. The furnace temperature was raised from room temperature to 480°C in four hours, held at this temperature for fifteen minutes, and returned to room temperature in six hours. Three configurations were used and these are shown in Figure 5. In all cases, the barium fluoride cracked when removed from the furnace, indicating a highly stressed seal. The cracking seemed to be preferential, resembling crystal cleavages. Some seals indicated that too much silver chloride was used, while others appeared to have too little. It is felt that a successful sealing procedure is dependent upon the amount of AgCl used and the method in which it is applied to the sealing glass or the barium fluoride window.

To control the amount of silver chloride for each seal, silver chloride preforms have been ordered. The preforms are washer-shaped with dimensions of 0.625" O.D., 0.437" I.D., and 10 to 15 mils thick.

Thicker barium fluoride windows (0.125" thick) have been ordered to provide more mechanical strength and less likelihood of cleavage behavior.

Attempts to seal barium fluoride to metal have been made. The metals selected for the seal were chosen for their thermal expansion coefficients. The coefficients are:

Stainless steel, #304 - $170 \times 10^{-7}$ per °C

Aluminum - $200 \times 10^{-7}$ per °C

Copper (OFHC) - $160 \times 10^{-7}$ per °C.

Barium fluoride has a coefficient of thermal expansion of $184 \times 10^{-7}$ per °C. Silver chloride was not used in these attempts. The intermediary used was a copper sealing glass developed by the Corning Glass Works designated as 7295 glass. The 7295 glass is in powder form and has a coefficient of thermal expansion of $154 \times 10^{-7}$ per °C, and melts near 500°C.

Two materials have been tried and the configurations are shown in Figure 6. The 7295 glass is fired onto the metal, the barium fluoride window is set in place, and the assembly is temperature cycled in the furnace as previously mentioned.

A successful stainless steel to barium fluoride seal was made, but cracked when the surfaces were being cleaned. This occurrence indicates excessive stress in this seal.

A successful seal using 7295 glass has been made to copper, and appears promising. It may be possible to make seals to copper washers and solder the assembly into metal dewars.

Successful seals of barium fluoride to glass have been made by epoxy cement as an intermediary, but these seals have a limited lifetime due to the porous nature of the cement and outgassing of the epoxy into the vacuum space.

Successful barium fluoride seals will undergo environmental testing to establish material reliability under conditions simulating device application.

### 3.3.3 Silicon Windows

Silicon as a detector window material fulfills all of the requirements of a desirable window except that of maximum transmittance. Figure 7 shows the transmission of uncoated silicon. Experimental tests have been run on 10-, 15- and 20-mil thicknesses with results showing no appreciable difference in transmission. The transmission loss in silicon is due mainly to reflection losses at the surface because of the high index of refraction ($n \approx 4$). Silicon may be made practically transparent (100% transmittance) at particular wavelengths by application of a quarter-wavelength coating of silicon monoxide whose index of refraction is approximately the square root of the refractive index of germanium.

Figure 8 shows the improvement in transmission obtained by a silicon monoxide coating for the 5 micron region. Silicon monoxide coated windows are presently being used on commercial detectors

marketed by Philco Corporation, and exhibit stable and reliable performance.

## SECTION IV - CONCLUSIONS

The metallurgical and material evaluation program is progressing satisfactorily after an initial delay in acquisition of material and processing equipment. An estimated 15% of the program was accomplished during the first quarter.

Attempts to achieve a vacuum tight barium fluoride window seal to glass have been unsuccessful to date; however, successful seals have been made to copper tubing.

## SECTION V - PROGRAM FOR THE NEXT INTERVAL

1. Continue metallurgical studies and material evaluation.
2. Continue barium fluoride sealing technique investigations.
3. Improve germanium contacts.
4. Design and evaluate a simpler cell mount in an attempt to reduce cost, improve alignment, and provide improved thermal characteristics.
5. Build and evaluate a new material evaluation configuration.
6. Assemble test equipment.
7. Fabricate and test three engineering samples.

## SECTION VI - PUBLICATIONS, REPORTS AND CONFERENCES

No publications, lectures, or reports pertaining to work developed on this contract were issued or given during the period covered by this report.

One conference pertaining to this contract was held during the quarter covered by this report. The conference was held on 25 February 1963 at the facilities of the United States Army Electronics Materiel Agency in Philadelphia, Pennsylvania, with representatives of the USAEMA and of the Philco Corporation in attendance.

## SECTION VII - IDENTIFICATION OF PERSONNEL

The key technical personnel who have taken part in the work covered by this report are listed below and the approximate man-hour figures are also given for three general categories of technical assistance furnished to the key personnel during the quarter. Background resumes of the key technical personnel are also included in this section.

| Name | Approx. Man-hours |
|---|---|
| Cohen, B. | 304 |
| Devito, L. | 20 |
| Dunkle, R. | 30 |
| Irwin, E. | 61 |
| Peterson, A. | 50 |
| Skvarna, D. | 310 |
| Snyder, C. | 98 |
| Total | 873 |
| Misc. Engineering | 20 |
| Technicians and Operators | 560 |
| Draftsmen and Model Makers | 62 |

## RESUMES

### Weingrad, Richard H. - Department Manager, Infrared

Mr. Weingrad received his education at George Washington University, where he received his B.S. in Chemistry and completed three years of graduated study in Physical Chemistry. He joined Philco Corporation in 1958.

He was formerly responsible for transistor device pilot production and later for manufacture of production and prototype equipment at Philco's Lansdale Division. His professional engineering experience of over 15 years includes 4 years at the Lansdale Division and 6-1/2 years in electromechanical design and production engineering of ordnance fuzing systems at the Army's Diamond Ordnance Fuze Laboratories. Other engineering experience was gained in the design, development, and construction of photographic and optical instruments at the Eastman Kodak Camera Works and various technical service establishments.

Mr. Weingrad is a member of Sigma Xi and the American Chemical Society. He has published a number of papers in the fields of explosives and electrochemistry. He has a patent to his credit and several pending.

### Irwin, Edgar L.

Mr. Irwin received his B.S. degree from Loyola of Chicago in 1954.

He has participated extensively in the design and development of indium antimonide photovoltaic, photoconductive, and photoelectromagnetic infrared detectors. He established a facility for the production of indium antimonide grown junction photovoltaic infrared detectors.

Mr. Irwin joined Philco Corporation in 1962 as supervisor of the development section, Infrared Department. He is directly responsible for the successful development of a photoconductive indium antimonide infrared detector now available commercially from Philco. He is also contributing materially to the indium arsenide detector program.

Skvarna, Donald G.

Mr. Skvarna received a B.S. degree in Electrical Engineering from the University of Pittsburgh in 1959 and has taken postgraduate courses in transistor technology.

He has had experience in the area of infrared detector fabrication, and was chiefly responsible for developing and implementing a processing technique for the manufacture of multi-element indium antimonide detector arrays.

Mr. Skvarna has also had experience in electronic circuitry design, detector measurements, solid state parameter measurements, thin film deposition and control, and infrared instrumentation.

Recently he has worked on specifications for indium arsenide detectors and set up instrumentation for the measurement of parameters of gallium arsenide infrared emitting diodes.

He is a member of the American Institute of Electrical Engineers.

Snyder, Carl R.

Mr. Snyder has studied the technology of glass for twelve years.

He joined Philco Corporation in 1958. He has wide experience with problems of design, production, and manufacture of glassware. At Philco he has been concerned with supervising the pilot line for the fabrication of infrared detector bottles, designing jigs and fixtures instrumental in the fabrication of these bottles, and supplying the necessary glassware for research. He was instrumental in the design of the IR detector bottles. Recently he received a Philco merit award for an improved method of sealing silicon and sapphire to glass.

Before coming to Philco, Mr. Snyder was employed at Fredericks Company of Philadelphia as head glassblower from 1948 to 1958. There he was concerned with specifications and procedures involved in the manufacture of glassware, helped to engineer new projects, made samples of special scientific glassware, designed jigs and fixtures, and was a troubleshooter in glassware production.

Mr. Snyder is a member of the American Scientific Glassblowers Society.

DeVito, Leo

Mr. DeVito received the B.S. degree in Industrial Engineering from Purdue University in 1954.

Immediately after graduation, Mr. DeVito joined the Industrial Engineering Department of the Lansdale Division of Philco Corporation, where he worked in cathode ray tube, receiving tube, and semiconductor operations.

In 1958 Mr. DeVito transferred to the Electrochemical Transistor department, and was responsible for all mechanical specifications, such as package design work, and design, construction, installation, and run-in of automatic equipment.

In 1963 Mr. DeVito joined the Infrared Department as a manufacturing engineer. In this assignment he is responsible for all mechanical specifications of the equipment and devices used therein. He is presently engaged in writing chemical and processing specifications for infrared devices. In addition, he serves as liaison between the Engineering and Production departments in an administrative capacity, and is responsible for the installation of equipment and the layout of the presently expanding Infrared department.

Cohen, Barry

Mr. Cohen received the B.Ch.E. degree from the City College of New York in 1963.

He had acquired considerable experience in the solid state field while gaining his education. In 1960, while attending school in the evening, he worked on the metallurgy of semiconductor components and on the pilot line of a silicon mesa transistors. He also worked on silicon solar cells during the summer of 1962.

Based on his work on the silicon mesa transistor, Mr. Cohen wrote an undergraduate thesis entitled "Manufacture of the Silicon Mesa Transistor." This was subsequently published in the engineering journal of the City College of New York. In addition, Mr. Cohen co-authored an article on solar cells for the same publication.

Mr. Cohen joined Philco Corporation upon his graduation in January, 1963 as a Junior Engineer in the engineering section of the Infrared Department. He was initially assigned to the Gallium Arsenide Emitter program, and is currently working on the metallurgy of gold-doped germanium.

Dunkle, Richard B.

Mr. Dunkle received the B.S. degree in Chemical Engineering from Drexel Institute of Technology in 1948.

He has nine years of experience in semiconductor work in the metallurgy of germanium, silicon, gallium arsenide, and indium antimonide, including work on diffusion related to germanium and silicon. He has two years of experience in the development of silicon photovoltaic devices, including silicon solar cell pilot production. He has recently been responsible for the product and process engineering of silicon coaxial microwave diodes and gallium arsenide K-band mixers.

Peterson, Alden

Mr. Peterson received his B.S. degree in Physics from Bucknell University in 1956.

He has been with Philco for six years and has been concerned with projects related to the metallurgy of silicon, germanium, gallium arsenide, and indium antimonide as a research and development engineer. The major projects with which he has been associated include dendritic growth of germanium and silicon crystals, float zone refining of silane deposited silicon, measurements of solid state properties of semiconductor materials such as lifetime, Hall effect properties, and dislocation studies.

His recent work includes studies related to germanium temperature sensors, gallium arsenide thermistors, and special semiconductor materials used as infrared detectors; diffusion studies of various diffusants in germanium, silicon, gallium arsenide, and indium antimonide.

# APPENDIX - TABLES AND FIGURES

TABLE 1

PARAMETER MEASUREMENTS - INGOT NO. B120

Supplier: Rare Metals Derivatives

No. of Passes: 8

Ingot Weight: 397.7 g

Avg. Resistivity: 40 ohm-c

Dopant Amounts: Au - 4.0 g
Sb - 0.39 g

Life Time:

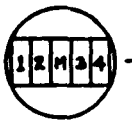
| Parameter | | Test Wafer No. 1 | 5 | 8 | 13 | 18 |
|---|---|---|---|---|---|---|
| ρ at 300°K, ohm-cm | 1 | 3.80 | 2.65 | 2.33 | 1.93 | 1.54 |
|  | 2 | 3.18 | 2.56 | 2.48 | 2.11 | 1.68 |
| | M | 2.92 | 2.31 | 2.17 | 1.88 | 1.49 |
| | 3 | 2.99 | 2.38 | 2.27 | 1.90 | 1.83 |
| | 4 | 4.24 | 2.62 | 2.45 | 2.14 | 1.67 |
| Cooling Ratios (x K/1) | 1 | 2.70 | 33.0 | 280.0 | 413.0 | 339.0 |
| | 2 | 3.34 | 45.0 | 68.0 | 260.0 | 400.0 |
| | 3 | 12.40 | 63.0 | 77.0 | ---- | ---- |
| Dislocation Density, pits/cm$^2$ | | 5800 | 7350 | 9550 | High | High |
| Hall Measurements at 300°K: | | | | | | |
| ρ, ohm-cm | | ---- | ---- | 2.56 | 2.08 | 1.72 |
| $R_H$, cm$^3$/coulomb | | ---- | ---- | 7000 | 6290 | 4680 |
| μ, cm$^2$/volt sec | | ---- | ---- | 2730 | 3020 | 2720 |
| n, carriers/cm$^3$ (x $10^{15}$) | | ---- | ---- | 1.05 | 1.17 | 1.57 |

TABLE 1

UREMENTS - INGOT NO. B120

No. of Passes: 8 Date: 1/13/63

Avg. Resistivity: 40 ohm-cm. Orientation: <111>

Life Time:

| Test Wafer No. | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 8 | 13 | 18 | 23 | 28 | 33 |
| 65 | 2.33 | 1.93 | 1.54 | 1.16 | 1.09 | 0.460 |
| 56 | 2.48 | 2.11 | 1.68 | 1.43 | 1.01 | 0.715 |
| 31 | 2.17 | 1.88 | 1.49 | 1.25 | 0.77 | 0.544 |
| 38 | 2.27 | 1.90 | 1.83 | 1.34 | 0.93 | 0.463 |
| 62 | 2.45 | 2.14 | 1.67 | 1.56 | 1.34 | 0.422 |
| 0 | 280.0 | 413.0 | 339.0 | 225.0 | 193.0 | ---- |
| 0 | 68.0 | 260.0 | 400.0 | 190.0 | 173.0 | ---- |
| 0 | 77.0 | ---- | ---- | ---- | 200.0 | ---- |
| 50 | 9550 | High | High | High | High | ---- |
| - | 2.56 | 2.08 | 1.72 | 1.42 | ---- | ---- |
| - | 7000 | 6290 | 4680 | 3020 | ---- | ---- |
| - | 2730 | 3020 | 2720 | 2160 | ---- | ---- |
| - | 1.05 | 1.17 | 1.57 | 2.42 | ---- | ---- |

TABLE 2

EVALUATION SUMMARY OF CELLS FABRICATED F

| Wafer # | Cell # | Detectivity (D*) (x $10^9$) | Bias Voltage | Resistance at Forepump Pressure of 15 μ (K) | Load Resistance (K) | Bias Current μamps | Signal Voltage μvolts | Noi Vol μvo |
|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 2.0 | 80 | 400 | 1000 | 57 | 300 | . |
| | 2 | 1.35 | 80 | 200 | 100 | 265 | 210 | . |
| | 3 | 1.53 | 80 | 220 | 1000 | 67 | 160 | . |
| 3 | 1 | 2.2 | 40 | 250 | 1000 | 32 | 110 | . |
| | 2 | 1.5 | 60 | 320 | 1000 | 45 | 145 | . |
| 4 | 1 | 1.66 | 60 | 180 | 1000 | 50 | 100 | . |
| | 2 | 1.00 | 60 | 200 | 100 | 200 | 115 | . |
| 6 | 1 | 1.40 | 80 | 225 | 1000 | 65 | 190 | . |
| 7 | 1 | 1.72 | 80 | 220 | 1000 | 66 | 165 | . |
| | 2 | 1.50 | 40 | 220 | 100 | 125 | 96 | . |
| 9 | 1 | -- | -- | -- | -- | -- | -- | - |
| | 2 | -- | -- | -- | -- | -- | -- | - |
| 10 | 1 | 1.21 | 40 | 550 | 1000 | 27 | 150 | . |
| | 2 | -- | -- | -- | -- | -- | -- | - |
| 11 | 1 | 1.75 | 60 | 320 | 100 | 140 | 160 | . |
| | 2 | 1.37 | 80 | 250 | 1000 | 64 | 150 | . |
| | 3 | 1.50 | 60 | 320 | 1000 | 46 | 180 | . |
| | 4 | 1.24 | 40 | 270 | 1000 | 32 | 84 | . |
| | 5 | 1.05 | 60 | 220 | 1000 | 49 | 105 | . |
| 12 | 1 | 1.7 | 40 | 340 | 100 | 90 | 115 | . |
| | 2 | 1.17 | 80 | 320 | 1000 | 61 | 220 | . |
| 14 | 1 | 1.8 | 60 | 240 | 1000 | 48 | 115 | . |
| | 2 | 1.58 | 60 | 350 | 1000 | 44 | 190 | . |
| | 3 | 1.41 | 80 | 300 | 1000 | 62 | 200 | . |
| 15 | 1 | 1.5 | 40 | 380 | 1000 | 31 | 120 | . |

TABLE 2

OF CELLS FABRICATED FROM INGOT NO. B120

| e | Bias Current μamps | Signal Voltage μvolts | Noise Voltage μvolts | Room Temperature $R_{300}$ Resistance (ohms) | Liquid Nitrogen $R_{77}$ Resistance (Kohms) | Ratio of $R_{77}/R_{300}$ (x $10^3$) |
|---|---|---|---|---|---|---|
| | 57 | 300 | .75 | 2.6 | 600 | 230 |
| | 265 | 210 | .78 | 2.4 | 440 | 183 |
| | 67 | 160 | .52 | 3.0 | 320 | 107 |
| | 32 | 110 | .25 | 3.0 | 400 | 133 |
| | 45 | 145 | .48 | 2.5 | 450 | 180 |
| | 50 | 100 | .31 | -- | -- | -- |
| | 200 | 115 | .46 | 3.0 | 300 | 100 |
| | 65 | 190 | .68 | 3.0 | 500 | 167 |
| | 66 | 165 | .48 | 3.0 | 320 | 107 |
| | 125 | 96 | .35 | 3.0 | 350 | 116 |
| | -- | -- | -- | -- | -- | -- |
| | -- | -- | -- | -- | -- | -- |
| | 27 | 150 | .62 | 5.0 | 650 | 130 |
| | -- | -- | -- | -- | -- | -- |
| | 140 | 160 | .46 | 3.0 | 325 | 108 |
| | 64 | 150 | .55 | -- | 600 | -- |
| | 46 | 180 | .60 | 3.0 | 500 | 167 |
| | 32 | 84 | .34 | -- | 650 | -- |
| | 49 | 105 | .50 | -- | -- | -- |
| | 90 | 115 | .52 | 3.8 | 550 | 145 |
| | 61 | 220 | .94 | 3.2 | 460 | 144 |
| | 48 | 115 | .32 | 3.0 | 460 | 153 |
| | 44 | 190 | .60 | 3.0 | 550 | 183 |
| | 62 | 200 | .71 | -- | 450 | -- |
| | 31 | 120 | .40 | 3.0 | 600 | 200 |

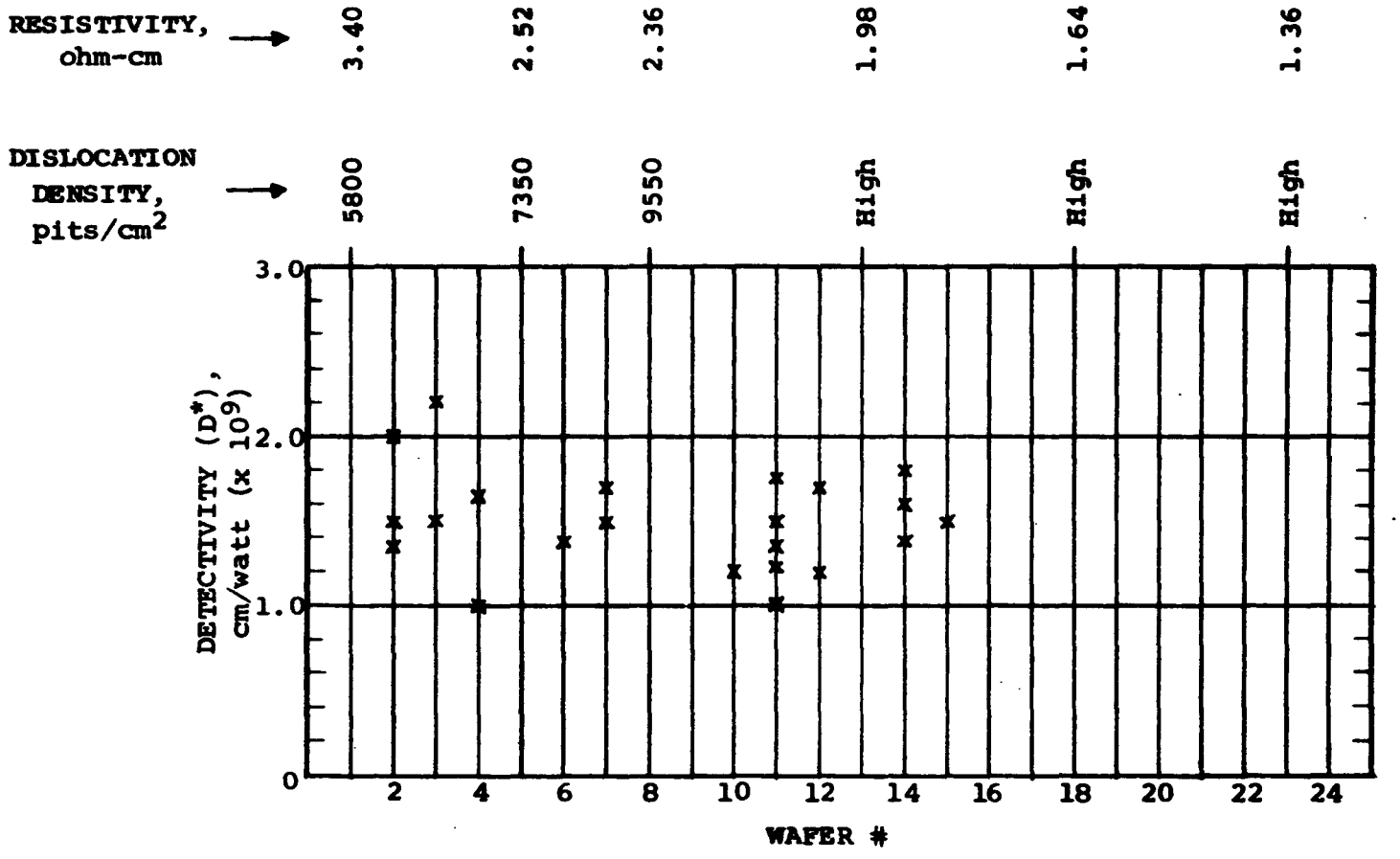



Figure 1. Graphic presentation of evaluation data - Ingot No. B120

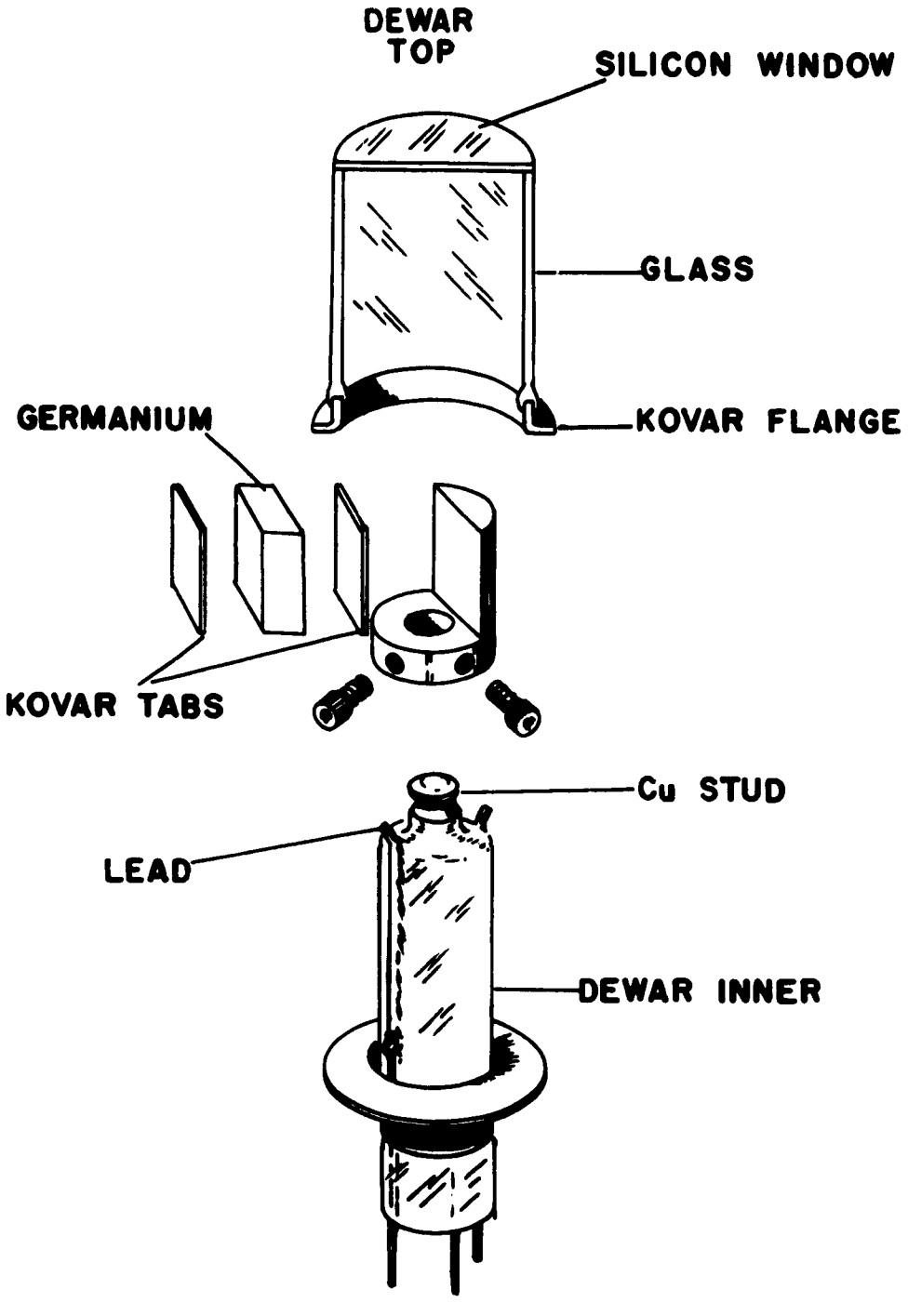



Figure 2. Preliminary test dewar

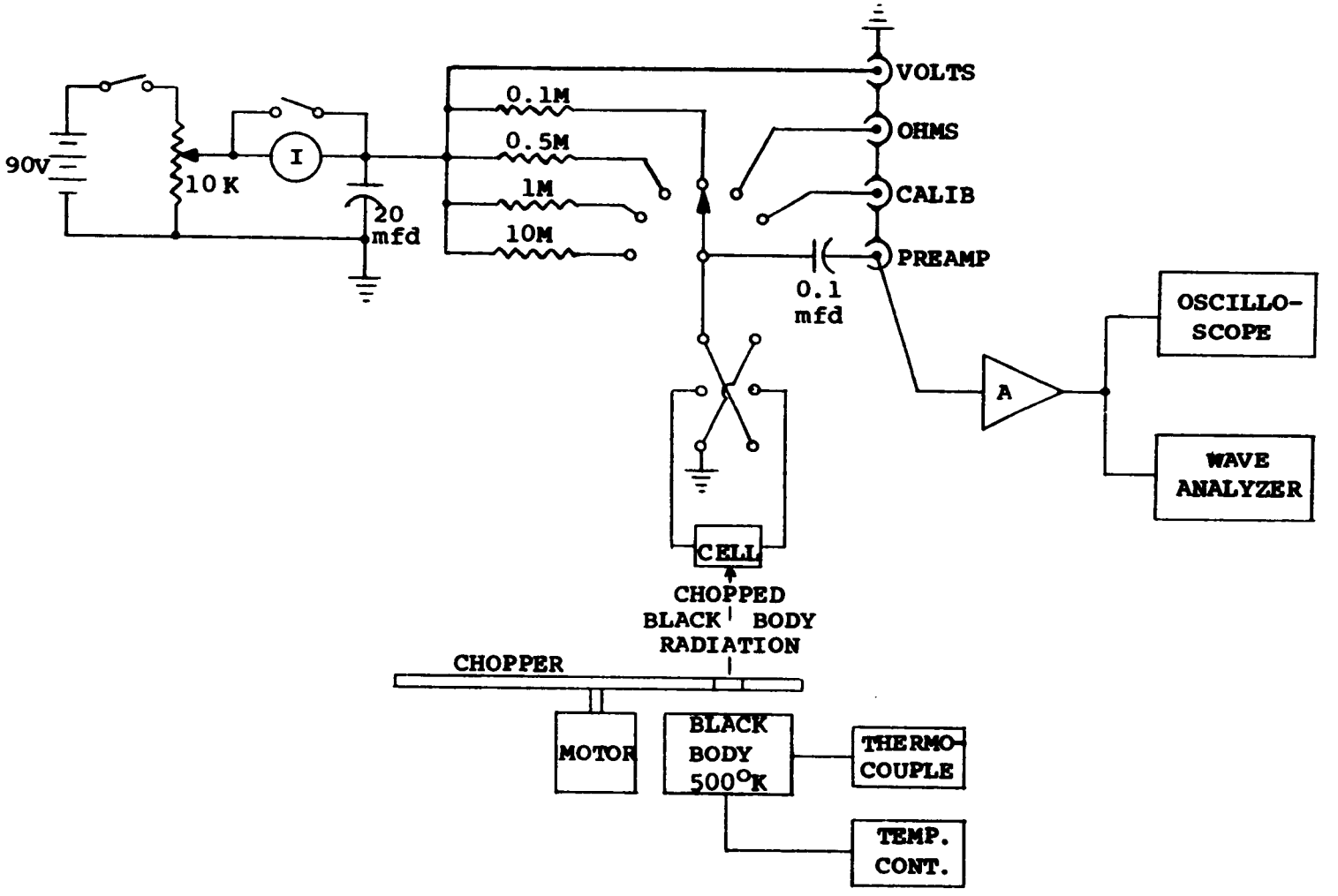



Figure 3. Testing circuit for gold-doped germanium infrared detectors

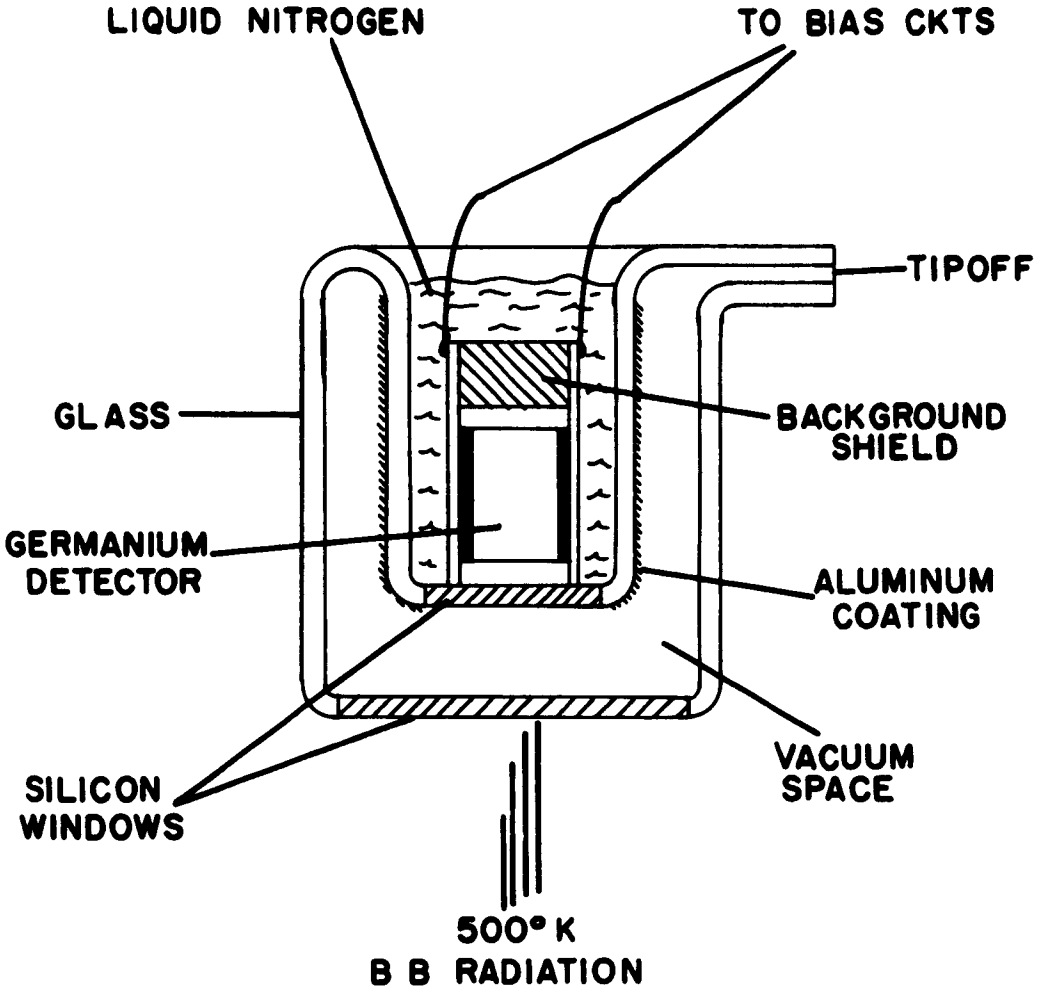



Figure 4. Contemplated test fixture

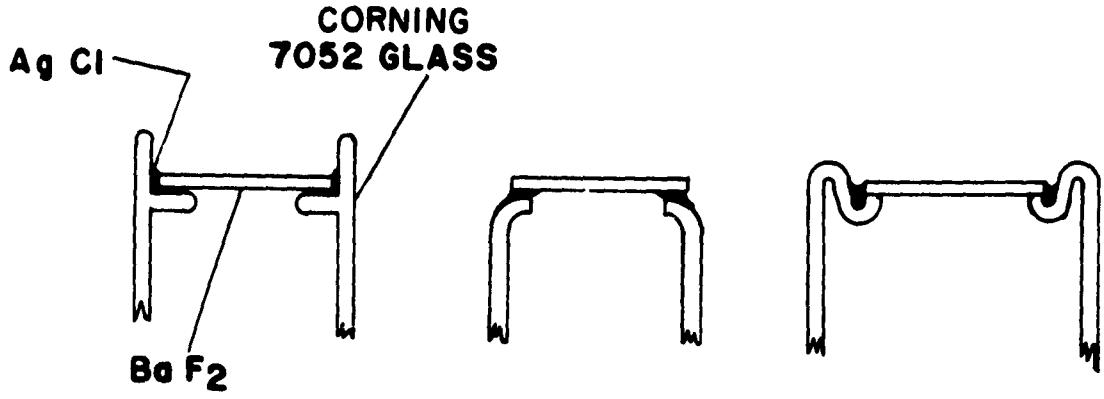



Figure 5. Configurations of barium fluoride to glass seals

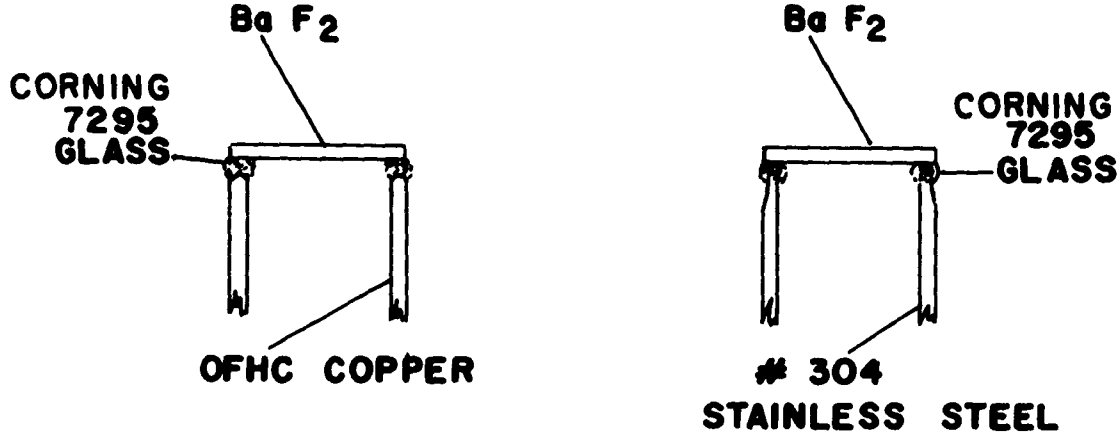



Figure 6. Configurations of barium fluoride to metal seals

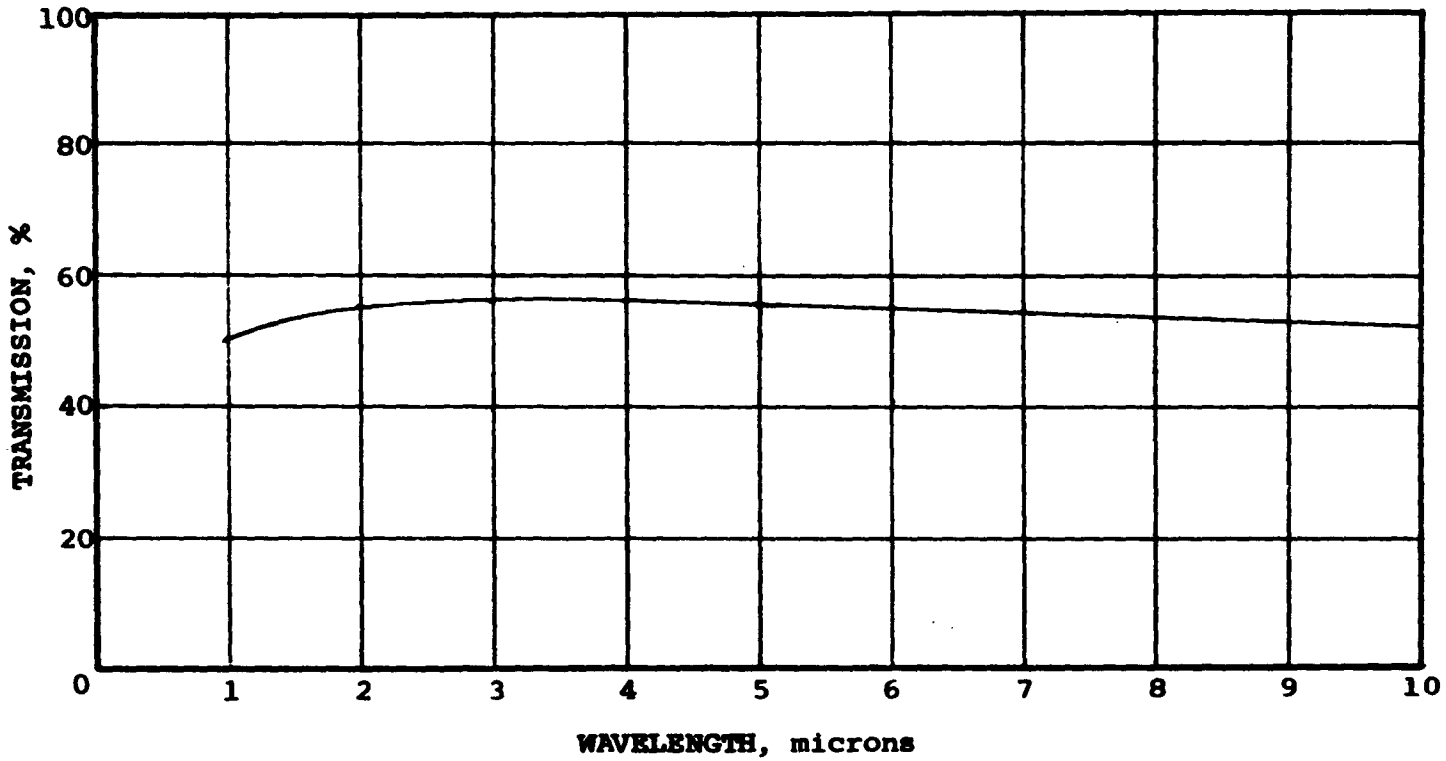



Figure 7. Transmission curve, uncoated silicon

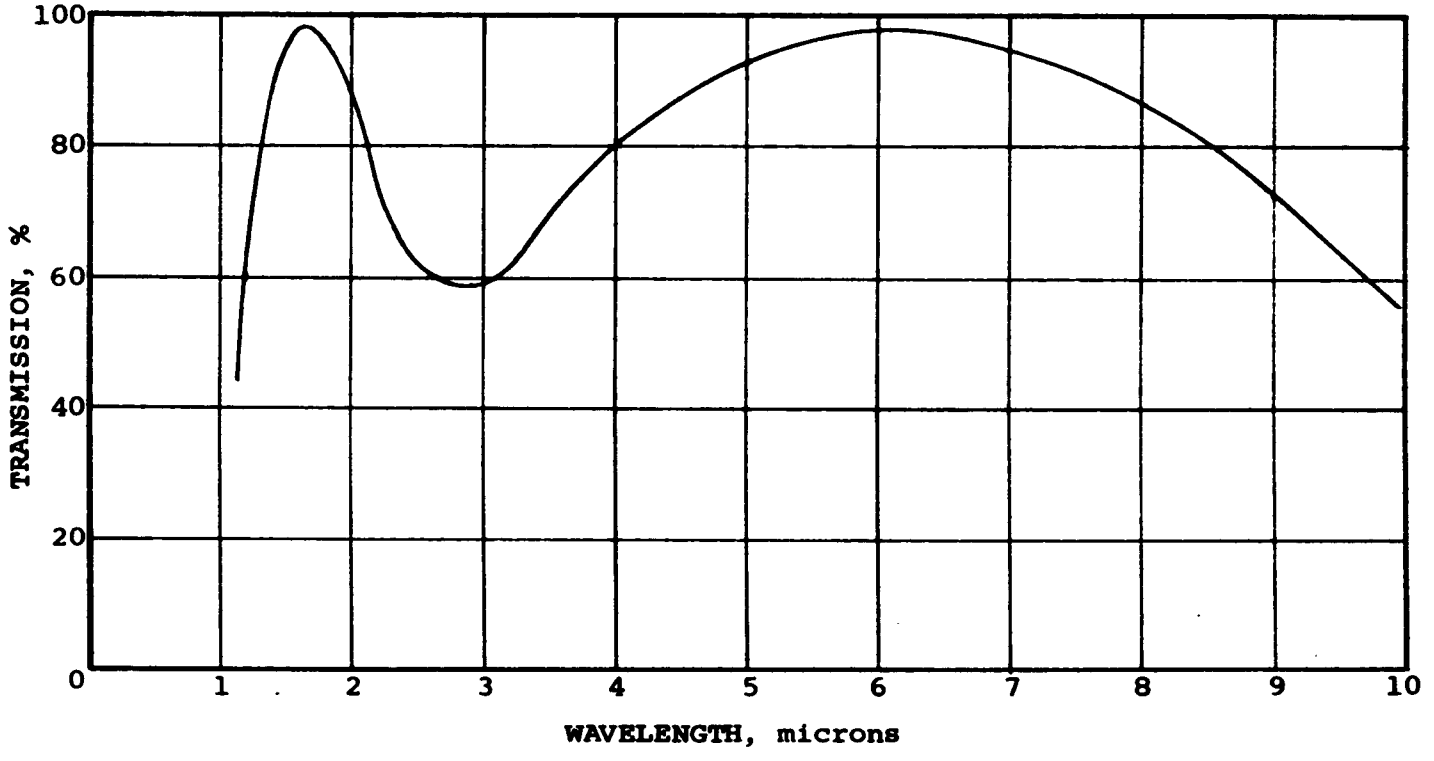



Figure 8. Transmission curve, SiO-coated silicon